How High Energy we need for the Muon Collider?

Yang Bai

with **Anupama Atre and Estia Eichten**

Theoretical Physics Department, Fermilab

March 5, 2008

Outline

Motivation

- Using a statistical way to study the parameter space of mSUGRA.
- Understanding the distributions of the spectrum of supersymmetric particle masses.
- Obtaining a rough estimate of the energy needed for the future muon collider in order to cover all or majority of supersymmetric particle masses.

Finding Good Points

- Starting from a random point in mSUGRA with 5 parameters:

$$m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ \mu\,.$$

- Calculate the MSSM mass spectrum, the relic density of the lightest neutralino $\tilde{\chi}_1^0$, $Br(b \to s\gamma)$, $\Delta\rho$, $(g-2)_\mu$ and $B_s \to \mu^+\mu^-$. [All of these quantities can be calculated through the software MICROMEGAS using the package SUSPECT 2.3.]
- If following constraints are satisfied,

$$0.086 < \Omega_{\tilde{\chi}_1^0} h^2 < 0.118\,,\ 2.8 \times 10^{-4} < Br(b \to s\gamma) < 4.6 \times 10^{-4}\,,$$
$$\Delta\rho < 2 \times 10^{-3}\,,\ (g-2)_\mu < 5.1 \times 10^{-10}\,,\ B_s \to \mu^+\mu^- < 9 \times 10^{-6}$$
$$m_h > 100\ \text{GeV}\,,\ m_{\tilde{\chi}_1^\pm} > 104.5\ \text{GeV}\,,$$
$$m_{\tilde{t}_1} > 101.5\ \text{GeV}\,,\ m_{\tilde{\tau}_1} > 98.8\ \text{GeV}$$

call this random point as a “good point”.

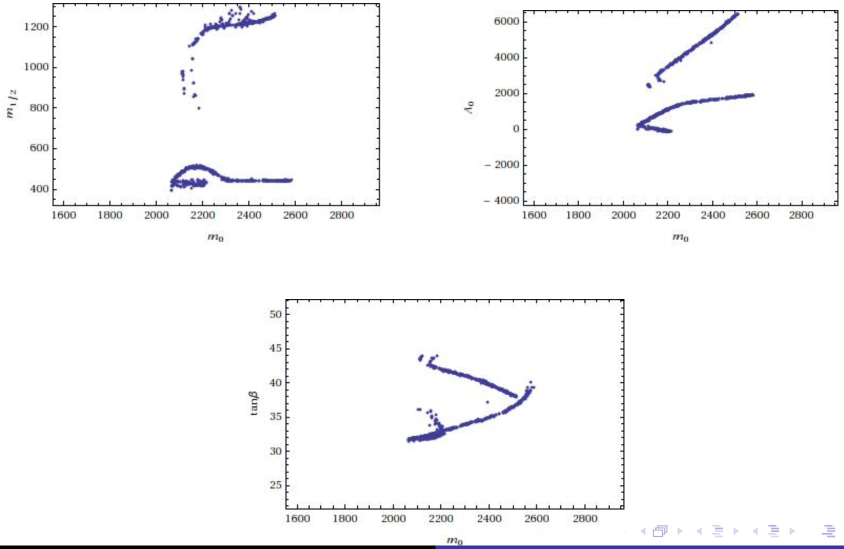
Finding Good Points

- A Fortran code has been developed to efficiently find a "good point" starting from a random point by minimizing the "chi-square".
- Restricting to the following range of parameter space,

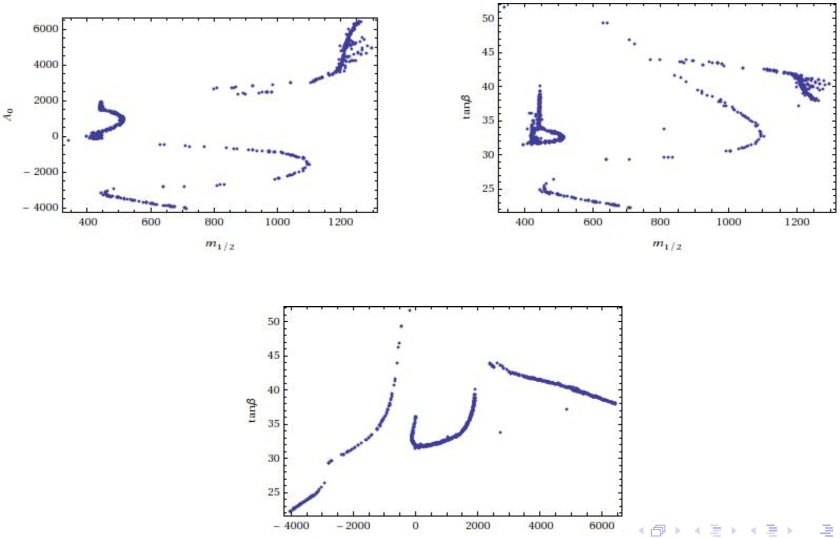
$$m_0 < 4000\,\mathrm{GeV} \quad m_{1/2} < 2000\,\mathrm{GeV} \quad |A_0/m_0| < 10 \quad 1 < \tan\beta < 60$$

- 1000 "good points" have been found.
- Analyzing the spectrum's out of these 1000 "good points", we will draw various distribution plots in turn.

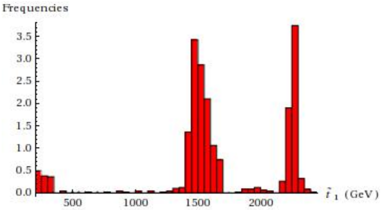
mSUGRA parameters



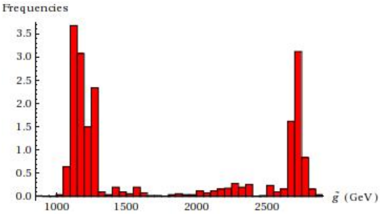
mSUGRA parameters



Spectrum

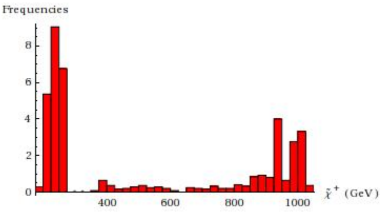


Stop Masses

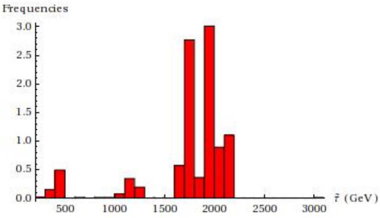


Gluino Masses

Spectrum

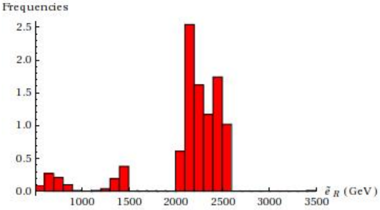


Lightest Chargino Masses

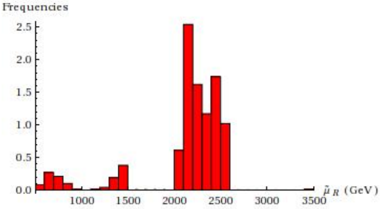


Lightest Stau Masses

Spectrum

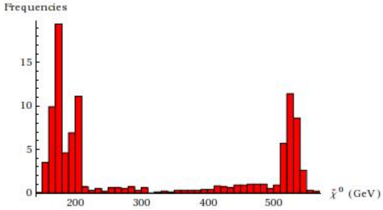


Selectron Masses

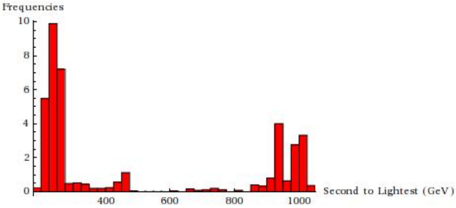


Smuon Masses

Spectrum



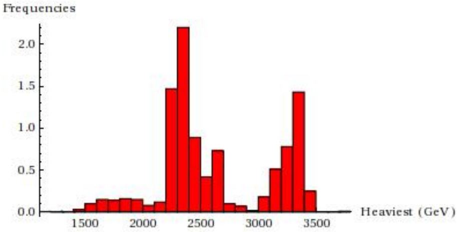
LSP Masses



Second Lightest Particle Masses

($\tilde{\chi}_1^+$: 872, $\tilde{\tau}_1$: 66, $\tilde{t}_1$: 62)

Spectrum



Heaviest Particle Masses ($\tilde{s}_L$: 937, $\tilde{g}$: 63)

- 99.6% of the heaviest particle masses are over 1500 GeV (only 4 out of 1000 are below it). Do we need a Muon collider with the center-of-mass energy to be $>$ 3 TeV?

Pattern of four lightest particles (1000 samples)

- $\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\chi}_3^0$: 858 (SPS 2)
- $\tilde{\chi}_1^0 < \tilde{t}_1 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0$: 62
- $\tilde{\chi}_1^0 < \tilde{\tau}_1 < \tilde{e}_R = \tilde{\mu}_R$: 57 (SPS 1a, 1b, 3 and 5)
- $\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\tau}_1$: 14 (SPS 4)
- $\tilde{\chi}_1^0 < \tilde{\tau}_1 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0$: 7
- $\tilde{\chi}_1^0 < \tilde{\tau}_1 < \tilde{t}_1 < \tilde{\chi}_1^\pm$: 2 (new)

Summary

- Based on a large scan of mSUGRA parameter space, the spectrum's of sparticle are studied in a statistic way.
- The lower mass bound of the heaviest sparticle requires an energy frontier lepton collider.
- Detailed studies of production and decay of sparticles of these 1000 “good points” are needed to have a more concrete answer for the center-of-mass scale of Muon collider.